TRIZ as general problem solving tool in secondary school teaching

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Abstract. Since 2014 we have been developing lessons for high schools to teach the TRIZ principles. These lessons have been given to qualified teachers, teacher students as well as high school students. During all lessons we have used a standard case for the problem solving exercise. We have used different lesson protocols and have analyzed which protocol leads to the most creative productivity in terms of number of unique ideas. During each problem solving lesson the participants have been working together in subgroups of 3 to 4 persons. One protocol containing our TRIZ version gave 100% increase in productivity on subgroup level compared with a protocol using a spontaneous problem solving brainstorm.

Keywords: high schools, inventive principles, problem solving

1 Introduction

High school education at pre-university level is facing new challenges. In the connected digital world people can easily access information and knowledge at any location. Memorizing knowledge is becoming less of a necessity. On the other hand, jobs/functions/roles in the work environment are continuously changing at a high pace. How does education prepare young people for being adaptive in such a changing environment? Furthermore, robotics and artificial intelligence are threatening to replace more and more of human jobs. In what way can human activities differentiate itself from such automatization? The World Economic Forum [1] has made a prognosis on what skills are important for future jobs; in the top 3 there are 1) complex problem solving, 2) critical thinking and 3) creativity. This study focuses on applying a method for creative problem solving based on the use of TRIZ inventive principles in high school education. Teaching creativity in such an environment is not new, though so far, the majority of these activities have taken place in Russia and the little relevant literature that has been translated into English is mostly focusing on younger students [2, 3]. That the subject is one of increasing interest can be seen, for example, by more recent publications around the topic of teaching creative thinking skills in High School education from the US [4], Korea [5] and Australia [6]. Moreover, at the MATRIZ TRIZfest-2017 International Conference in Krakow, a separate track was dedicated to teaching TRIZ and creativity in a high school environment [7,8].

In our approach the lessons aim at strengthening the skills of young students so that they will be better prepared for the future demands in their work and privat life. Based on our experiences of 4 years of teaching Teachers and Students in being creative by using the TRIZ way of thinking [9], we have investigated in what way the lessons can be most effective.

2 Outline of the lesson and the protocols

The lessons with teachers and teacher students have been executed as separate workshops for which there was 70 minutes time; the theory introduction was 50 minutes and the problem solving of the case took 20 minutes. Lessons with high school students took 40 minutes with 20 minutes theory and 20 minutes problem solving.

Besides these two types of lessons, we used three different protocols, and the results of these are compared in the current paper:

- Protocol 1 first taught the "theory on TRIZ" and then practiced "20 minutes problem solving".
- Protocol 2 first had an exercise of "10 minutes problem solving" then taught the "theory on TRIZ" and finished with another "10 minutes problem solving".
- Protocol 3 first had an exercise of "20 minutes problem solving" and then the "theory on TRIZ" was taught. Protocol 3 has been used to test the productivity of spontaneous ideas only.

Table 1 shows an overview of the groups and their respective protocols.

Table 1. Overview of lessons with problem solving brainstorm. The students have participated with all three protocols and the teachers with protocol 1 and 2.

Organisation	Participants	Total group size	Protocol
High School 1	Teachers	13	1
High School 2	Teachers	13	2
High School 3	Students	21	2
Teacher education	Teachers	44	1
High School 1	Students	8	3
High School 3	Students	25	3
High School 3	Students	28	1

The total number of participants was 152. The teachers that participated were of various disciplines, both technical and non technical subjects. The adult students from the teacher education were mathematics teacher students. The high school students were 16 year old pre-university students. Protocol three was not used with the teachers due to lack of time. Teachers and teacher students have been considered as a similar group since both groups are adults and have same education.

3 The TRIZ lesson

The TRIZ lesson contained information on the creative process with a stepwise approach. Due to the limited time, a lot of focus is on the mindset of TRIZ rather than on complex techniques. The following elements are part of this introduction: focus on the user [10], the analysis [11, 12], resource analysis [13], the use of already proven principles to solve problems [14], and teamwork.

To get the right focus on the user, as well as to get a fact-based analysis, it was stressed that curiosity, the search for answers that are not apparent in the initial problem statement, is crucial. This leads to questions such as:

- What is the need?
- What are the goals of different stakeholders?
- What are assumptions?
- What is the deepest cause of the problem?
- What are facts?
- What is the ideal result?

For the problem solving part, ten Inventive Principles were chosen. Based on the experience of teaching TRIZ at schools, these 10 principles are both, broadly interpretable and easy to grasp. They comprise:

01. Segmentation
02. Taking out
03. Local quality
07. Nesting
10. Preliminary action/prior action
13. The other way round
15. Dynamics
17. Another dimension
22. Blessing in disguise
25. Self-service

The normal procedure via the definition of technical parameter that improves and technical parameter that worsens and then searching in the contradiction matrix, has been eliminated [14]. Instead, we presented the TRIZ inventive principles as a general problem solving tool, suitable for both technical and non-technical problems.

We have experience true enthusiasm for this approach, not only for secondary school teaching but also for education of business sciences students at bachelor university level [15].

The ten inventive principles were introduced with a question and one or two well-known examples.

The questions that we used were:

1. “Segmentation”: Can I solve the problem by increasing the degree of segmentation, by using more pieces?

2. “Taking out”: A) Can I solve the problem by using a component of some other object? B) Can I solve the problem by taking out some property from the system?
3. “Local quality”: Can I solve the problem by creating dedicated properties/ functions to local areas of the object?
4. “Nesting”: Can I solve the problem by putting one object into the other?
5. “Prior action”: Can I solve the problem by doing something in advance to the moment it happens?
6. “The other way round”: Can I solve the problem by changing the roles in the interaction?
7. “Dynamics”: Can I solve the problem by making the object flexible or changing in time?
8. “Blessing in disguise”: Can I solve the problem by taking an advantage from something that is harmful?
9. “Another dimension”: Can I solve the problem by making use of another dimension in space or another type of use of the object?
10. “Self service”: Can I solve the problem by making use of an automatic functioning system?

These questions are less detailed than the original descriptions by the TRIZ theory, but in this way they are suitable for use by a large population of users of many ages and from many disciplines or backgrounds of education.

4 The problem solving case

We have used a standard case during the problem solving exercise. In past workshops we have experienced that the case is suitable as an exercise for practically anyone and that it has a high number of potential solutions; see Table 2. Furthermore, the case does not require specialist or in-depth prior knowledge:

4.1 The problem of the editors, Lack of advertisement space

The topic is a local monthly magazine made by volunteers. There are a fixed number of pages with advertisements. Size A5. Black and white print. In the situation described all advertisement pages are filled, however there is a new store in the neighborhood, which also wants to place an advertisement. There is no financial need to place more ads, the editors have fixed the number of pages at its current maximum, and they are already filled with existing shops.

What would you advise the editors to do, to give attention to the new store while keeping the existing limitations as explained above?

Use TRIZ inventive principles as much as possible.

Step 1: analyse the situation

Step 2: make a list of resources that you could use to solve this problem

Step 3: identify solutions using the 10 given inventive TRIZ principles

5 Quantitative measurement of the productivity

The solution space for this exercise was defined by the total number of unique solutions that were generated during the exercise by the 152 participants. These solutions are listed in Table 2.

Table 2. The solution space with 39 unique solutions.

#	Unique Solution
1	Make ads smaller to create space for new ad
2	Write a advertorial or interview for the new shop
3	Ask an existing ad to withdrawn
4	Make an insertable advertisement paper
5	Write a sentence to redirect interested person to a website, social media
6	Investigate which advertisements are liked most by the readers and withdraw one
7	Alternate per month which advertisement is placed
8	Distribute the magazine via the new shop
9	Create a combined advertisement of a group of shops
10	Show a logo or photo of the shop only
11	Make a puzzle exercise in the magazine with name of the shop as the answer and Price offered by the shop
12	Give a clothing to the deliverers with the name on it of the shop as sponsor
13	Make a wrapper around the magazine with the shop logo or name, let distributor make promotion
14	Make a watermark with the shop name
15	Shop sponsors activities announced in the magazine
16	Add a coupon to the newsmagazine for a free gift from the shop or pric reduction
17	Map of district with what is where
18	Smaller font size
19	Minimize or standardize number of words per article
20	Front or back side with ad
21	Print logo in margin of text
22	Increase paper size of magazine
23	Send newsletter with shop ad to readers by email
24	Music sensor that plays an add when you open the magazine
25	Harmonica-style folded magazine or part of it that can be extended
26	Print QR code
27	Shaded name of shop as background of text
28	Customer review article on the shop
29	Reading/coffee corner with the magazine in the shop
30	Name of the shop appear on the side of the magazines then you put one year of magazines together on the shelve

31	Reduce the number of images to create space for ad
32	If finished reading return the magazine to the shop in turn for a reward
33	Extra magazine e.g. on shops
34	Children's coloring page with name shop
35	Make an ad with different picture with different viewing angle
36	Make an ad with different layers
37	Ad with glow in the dark
38	Write name shop in acknowledgement section
39	Let distributor make promotion by talking to people during delivering the magazine

We compared for all subgroups (3-4 persons) the number of unique ideas that they have found. Figure 1 and Table 3 show the results.

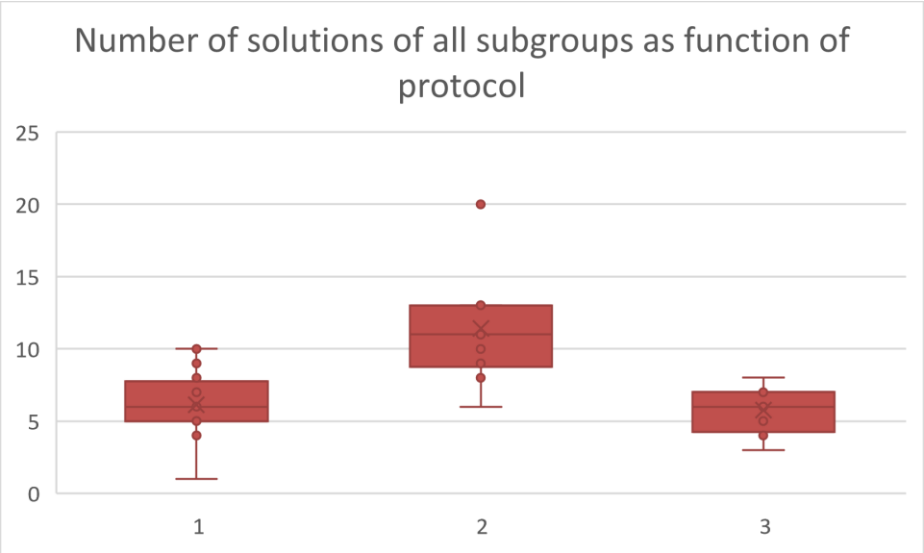

Fig. 1. Box and whisker plot of all subgroups as function of protocol (1, 2 or 3).

Table 3. Average and standard deviation for all subgroups of all three protocols.

	Protocol 1	Protocol 2	Protocol 3
Average	6,15	11,4	5,75
Standard deviation	2,21	3,81	1,67

The T-test has been done pairwise and the result shows that the averages of protocol 1 and 3 are both significantly lower than of protocol 2. Protocol 2 (that starts with a free

10 minutes problem solving session, then teaches the TRIZ theory and finally a 10 minutes problem solving session) has statistical significantly the highest productivity on subgroup level.

As described above, protocol 1 has first theory on TRIZ and then a 20 minutes problem solving session and protocol 3 has only a free problem solving session before the TRIZ theory has been introduced.

The difference between protocol 1 and 2 is remarkable. It can be explained that during protocol 2 the first brainstorm creates a beneficial mindset for the participants, that makes the processing of the theory session easier. Another explanation is that after the first problem solving session, a background problem solving process is activated in the participants, also known as an incubation process [16]. The latter hypothesis has not been researched further in the present paper.

The difference between the average score for protocol 1 and protocol 3 is not statistical significant. It shows that simply explaining the TRIZ theory in a short session does not necessarily lead to more creativity directly.

The gain in productivity (as averaged for all subgroups for each protocol) by protocol 2 is expressed by a 85% increase relative to protocol 1 and 100% increase relative to protocol 3.

When we compared in this study the number of solutions found per sub group by teachers or students we found no statistical difference between the averages of both type of participants, see Figure 2.

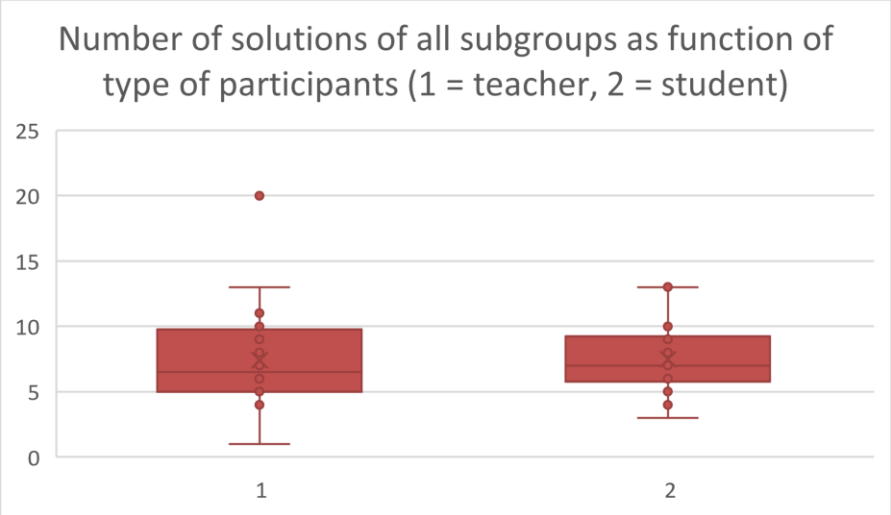

Fig. 2. Number of solutions of all subgroups (4 persons) as function of type of participants.

6 Discussion

This study demonstrates how the creativity of a small group in a teaching session can be strongly enhanced by choosing an optimal lesson protocol. The effect can be explained by creating the right mindset before the lesson on TRIZ theory is executed. This effect also raises the question in what other way can the creative mindset be enhanced? What factors are important? How can these be applied in a school setting? Those other factors may include the social functioning of the group (such as openness in communication, cooperation, building on each other, ability to postpone judgement), expert knowledge (having some prior experience or knowledge in this field) [17] and environmental factors (ambiance in room or organization) or mental preparation (being prepared for creativity by a certain exercise).

Another point of discussion is the similarity of results between protocol 1 and protocol 3. That all participants of the study have had university or pre-university education, and thus may have above average problem solving capacity could be one explanation. The limited time to explain and apply the TRIZ way of working may be another. It would be interesting to test the TRIZ method as explained in this study with participants that have a lower problem solving capacity, like lower educated participants or those with an autism spectrum diagnosis, as well as to run a comparable study with a more generous time schedule.

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